Sun-Tracking Solar Panel

Design Concepts and Overview

Department Project ID

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Contents

1.0 Introduction

Introduce your project as required; what it is, what you hope to accomplish, etc.

Need for solar panels

Tracking benefits

Choice of 2-axis tracking

- Solar panels are a common way of generating power in CubeSats – batteries risk exploding, running out of power, etc..
- However, fixed solar panels do not maximise solar energy gain most of the time due to them not facing the sun often, plus panels have relatively low efficiency (conventional cells are typically 13-22%, the best are multi-junction and yet only 30%)
- 2 axis tracking allows the solar panels to gain the maximum solar energy possible

- This project focuses on the mechanical design of a 2-axis tracking mount for a 1U CubeSat

Decided to go with design C – single panels with 2-axis hinges.

1.1 Scope

Highlight the scope from your project proposal

The scope of the project is to investigate the feasibility of a 2-axis solar panel tracking mount for a 1U CubeSat by researching designs and modelling the best in Autodesk Inventor. This model must meet Jaxa specifications for dimension, weight, and vibrational analysis, with FEAs completed in Inventor. Finally, a 3D model is printed demonstrating the concept.

1.2 Requirements

Highlight your success criteria – again this can be copied from your project proposal but please give concrete numbers!

1.3 Timeline

My project timeline for onboarding was:

Week	Onboarding session date	Aim
1	26/03	• PAST Onboarding Handbook and Github familiarization • Logbook setup and sharing with HR • General CubeSat learning • Browsing mechanical projects and pick one to work on
2	02/04	• Research 2 axis mounts
3	09/04	• Pick 3 possible designs and research strengths/weaknesses
4	16/04	• Pick one design to model in Inventor
5	23/04	• Start FEAs to show that JAXA specs are met • Work on finalising a CAD model draft
6	30/04	• Continue work on FEAs • Start work on Design Concept document.
7	07/04	• Continue FEAs • Continue work on design concept document
8	14/04	• Review Logbook and Design Concept docs for final submission

2.0 Two-Axis Tracking Feasibility

2.1 Overview of tracking types

This document's introduction outlines some benefits of implementing sun tracking solar panels on CubeSats. Now, this section will outline different tracking types used for solar panels in general, and which best suit a 1U CubeSat. The types that are investigated are single and dual-axis designs.

Current single axis tracking systems on Earth are divided into horizontal, vertical, and tilted axis tracking systems (Seme et al., 2020). Systems such as the tilted axis ones already demonstrate considerable solar radiation gains, with some of the most optimised seeing 96% of the radiation collected by 2-axis systems (Zhu et al., 2020). This is possible on Earth due to the sun following a predictable parabolic path across the sky for known latitudes, allowing most solar radiation to be collected a single tracking axis.

https://www.sciencedirect.com/science/article/pii/S2352484719304780#sec5

for reference that dual axis systems are more efficient (probs on earth)

and that they demand more maintenance and are more complex

Two-axis tracking further optimises energy efficiency by allowing panels to face fully perpendicular to the sun at any position in the sky (assuming no obstructions or limitations of mount). There are many different mechanism designs possible for two axis tracking,

- Mech designs for solar tracking: Many mechanism designs are possible. Serial mechanisms offer… while, Parallel mechanisms offer add stiffness and accurate motion, however this may not be necessary in a zero g environment. Serial mechanisms may be enough
- Design and implementation of a dual axis…: Two axis tracking has been demonstrated to be more efficient than fixed 30 deg. 24.6% more energy. The authors stated that the energy consumed in tracking was negligible
- This energy expenditure will potentially be lower in a zero g environment due to absence of gravity
- Innovative deployable system

However, this is only possible on earth due to the predictable parabolic path. Satellites such as the CubeSat increase the challenge by a) having small surface areas, meaning as much solar energy needs to be captured as possible, and b) by requiring payloads to be oriented in certain directions (e.g., cameras pointed to Earth), potentially angling CubeSat solar panels away from sun.

2.2 Mechanical Feasibility

- 1 para: Mass and volume constraints
- Degrees of freedom and how these are achieved with motors/actuators
- Thermal/stress
- Reliability: vibrations, *redundancies*

2.3 Electrical and Control feasibility

- Power budget

- Wiring challenges
- Alignment and control complexity?

2.3 Table Comparing Tracking Methods

	Degrees of freedom		
Factor	Fixed	1-axis tracking	2-axis tracking
Power gain	Low	Moderate	High
Power cost	Negligible	Low - Moderate	Moderate - High
Mass	Low	Moderate	Moderate - High
Complexity/risk of failure	Low	Moderate	Moderate - High

3.0 Design A – Two-Axis Tracking Gearbox

3.1 Background

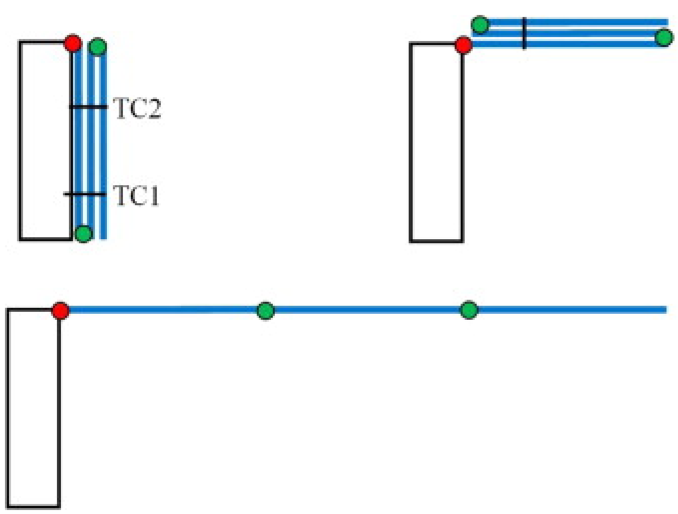
The design is adapted from one from a team at the University of Glascow, who designed a two-axis solar tracking system for their 3P PocketQubes (Li et al., 2017). PocketQubes are like smaller CubeSats, measuring 5x5x5cm, and the number of PocketQube units is referred to with a P (3P = 3 satellite units) (NASA, 2025). Since Design A is for a cubesat, a larger gearbox can be used on the top face. Additionally, the design is for 1U CubeSat instead of a 3P PocketQube, so panels of a reduced length must be used to fit in the JAXA envelope.

Moment of inertia is also briefly mentioned. This is defined as a measure of rotational resistance of an object which links torque and angular acceleration (Serway et al., 2017).

3.2 Functional Overview

The design utilises a two-axis system to track the sun. Two solar arrays are deployed from +X and -X sides of the CubeSat which can then unfold revealing additional panels (Figure 1). These are connected to a gearbox on the Z+ face of the CubeSat with shafts. Pre-deployment, the shafts have a hinge which allows the arrays to fold against the side faces of the CubeSat, held in place with fishing wire.

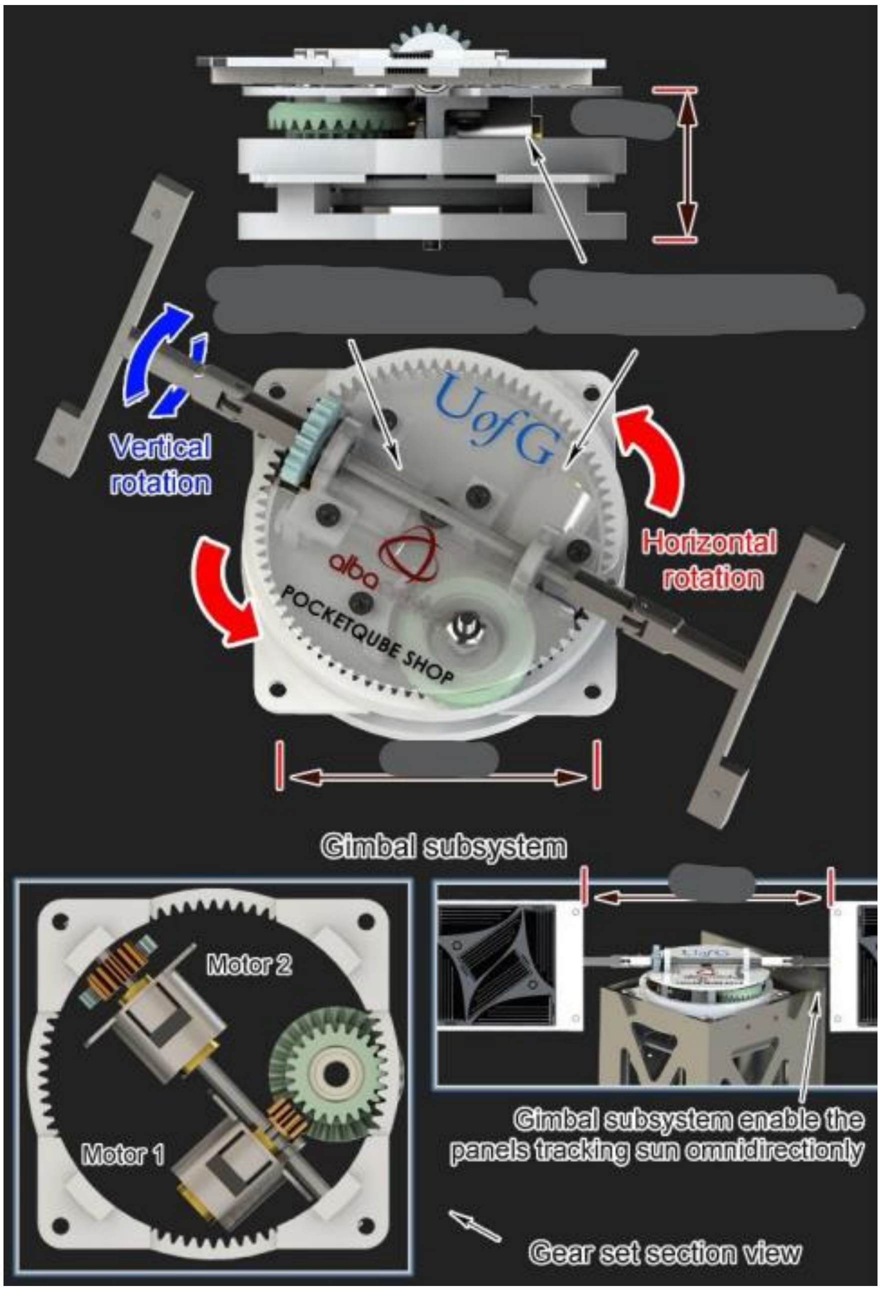
Figure 1. Panel deployment diagram.



Note. Screenshot from Santoni et al. (2014).

The system tracks the sun with two motors. One motor drives a gear that meshes with a fixed internal gear structure housed in the gearbox. This drives horizontal rotation of the gimbal system illustrated in Figure 2. A second motor situated on the rotating gimbal system drives a spur gear which meshes with a spur gear fixed on a shaft which can rotate. This provides a second axis of rotation - vertical rotation, illustrated in Figure 2.

Figure 2. Gearbox and gimbal diagram



Note. Modified screenshot from Li et al., 2017

3.3 Reasons for Design

3.3.1 Justification

Advantages of the design are that it provides full two axis rotation, with the full azimuth and elevation ranges are available for sun tracking. This means that no matter where the sun is, the panels can orient to face directly perpendicular to the sun and the CubeSat does not need to undergo additional reorientation. Furthermore, it allows longitudinal deployment of foldable solar panels, providing further surface area for power generation whilst stowing tightly along the sides of the satellite.

Another benefit is that tracking of two arrays (each containing several panels) can be achieved with only two motors. This means that the design does not cost as much energy as other tracking systems which require motors for each individual panel.

3.3.2 Challenges

Disadvantages of the design largely lie in its complexity and size. The gearbox takes up significant space in the CubeSat interior, which could be used for other systems. Additionally, the design is fairly complex with no redundancy measures. If one motor or gear fails, two axis tracking is lost for the whole satellite. Furthermore, springs may be required to pop the gearbox up so that the shafts can clear the cube's top rails. This added complexity may not be worth it. Lastly, longitudinal configuration of the deployed panels increases the satellite's moment of inertia which may affect attitude control.

4.0 Design B – Double Rocker

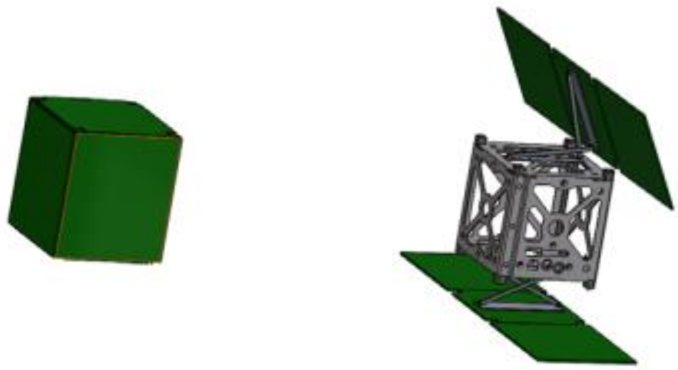
4.1 Background

This design is adapted from McGill (2018) and is for a 1U CubeSat. It involves a double rocker, which is a four-bar linkage where both side links can rock, and a revolute joint, which provides rotation around only a single axis.

4.2 Functional Overview

The design consists of a double rocker sitting on a revolute joint. The first axis of rotation is given by a motor driving a revolute joint, built into the cube. It allows the double rocker to spin 360 degrees. The second axis of rotation is the double rocker, which is driven by a motor and allows rotation about a second axis over 180 degrees.

Figure 3. Double rocker design for solar tracking



Note. Stowed configuration on left, deployed configuration on right. Screenshot from McGill (2018).

4.3 Reasons for Design

4.3.1 Justification

Advantages of the design are that full azimuth rotation is available due to the panels sitting on a rotating platform. Additionally, all 1U cube faces can be utilised for solar panel stowing, and this also means that either the top or bottom solar array will always be facing the sun. This adds redundancy protection if any of the motors fail. Lastly, the double rocker design does not take up much space when stowed.

4.3.2 Challenges

Challenges of the design are in its complexity and panel location. The double rocker adds complexity that may not be necessary.

Only the top or bottom panels can track the sun in a single moment.

5.0 Design C – Single Panels with 2-Axis Hinges

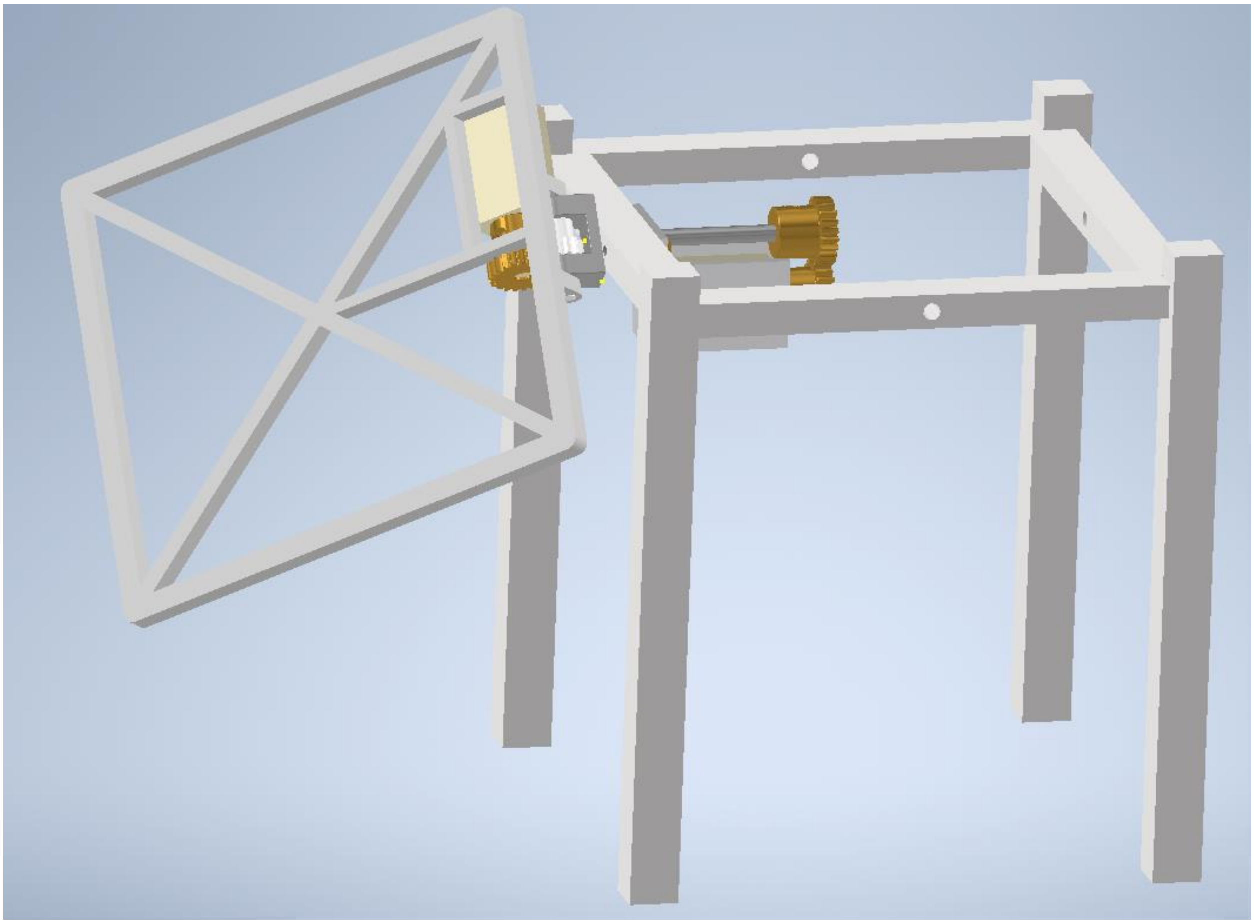
5.1 Background

This design is perhaps the simplest of the three. It currently uses N10 motors, which is a micro gearmotor – meaning a gearbox paired with a motor. They are very small, measuring approx. 30mm long (including d-shaft), 12mm heigh, and 10mm deep.

5.2 Functional Overview

The design has single solar panels mounted on the XY faces of the cube, and one stationary panel mounted on the Z+ face. The XY solar panels hinge at a single point where they meet the Z+ face. This hinging mechanism is what was further investigated in this project. If a solar panel is mounted on the X face, rotation about the X axis will be controlled by a spinning shaft coming from inside the cube. This first axis of rotation is actuated by an N10 motor mounted internally within the CubeSat chassis and drives the shaft. The secondary axis of rotation (about the Y axis in this example) is achieved via another N10 motor mounted on the underside of the solar panel near its top edge. When activated, the motor drives a spur gear that meshes with a fixed gear integrated in the hinge, providing elevation about a second axis.

Figure 4. CAD model of a single solar panel with 2-axis hinge.



Note. CAD model made in Autodesk Inventor by Shane van Bueren.

5.3 Component Selection

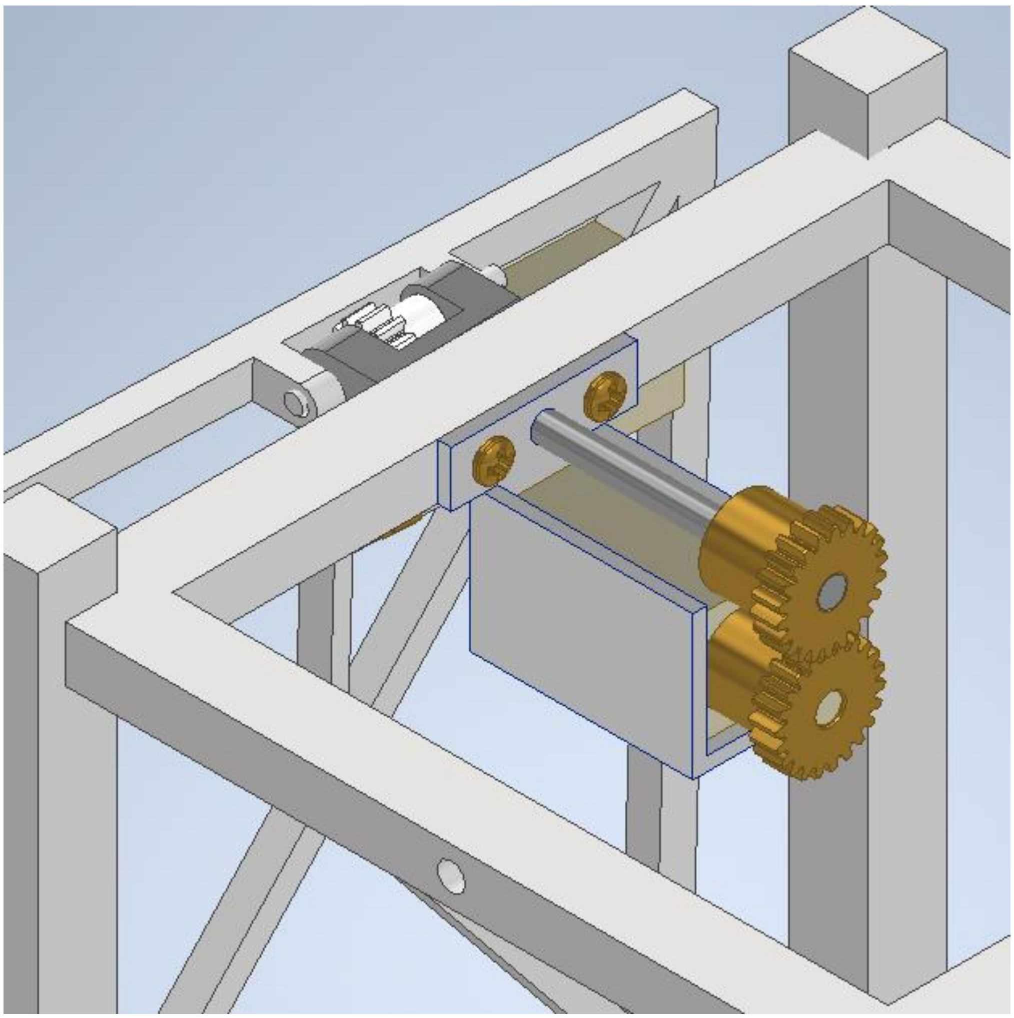
- Brass gears – 20 deg pressure angle, round with set screw, 0.5 module, 22 teeth - 2664N414
    - These are the gears used on the motors and rotating shaft. They were chosen due to small size and no interference with magnetic field
- Acetal plastic gear – 20 deg pressure angle, round bore, 0.5 module, 12 teeth – 2662N27
    - This gear is fixed on the hinge. It was chosen due to its very small size
- N10 motors
    - Dimensions (W*H*L): 12*10*~23.5mm + ~9.5mm D-shaft
    - Shaft dimensions (D*L): ⌀3*~9.5mm + 9mm long flat section
    - Weight: 8g
    - All metal construction including steel gears and gearbox endplates
    - Input voltage: nominally 6V, 0.4-12V

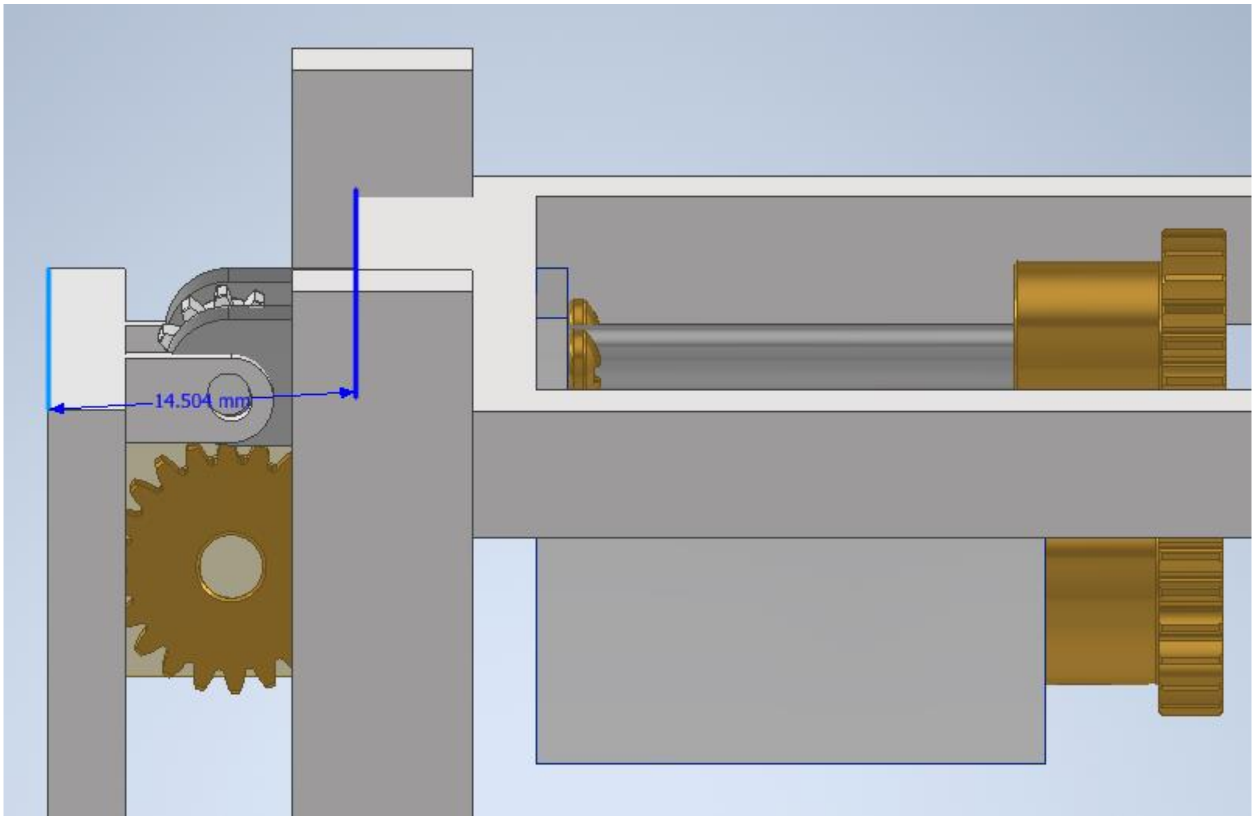
- No-load current (at 6V): ~0.085A
- Working current (at 6V): 0.2A-0.8A

5.4 Fabrication

5.4.1 CAD Drawings / Renders

All CAD models made in Autodesk Inventor by Shane van Bueren.

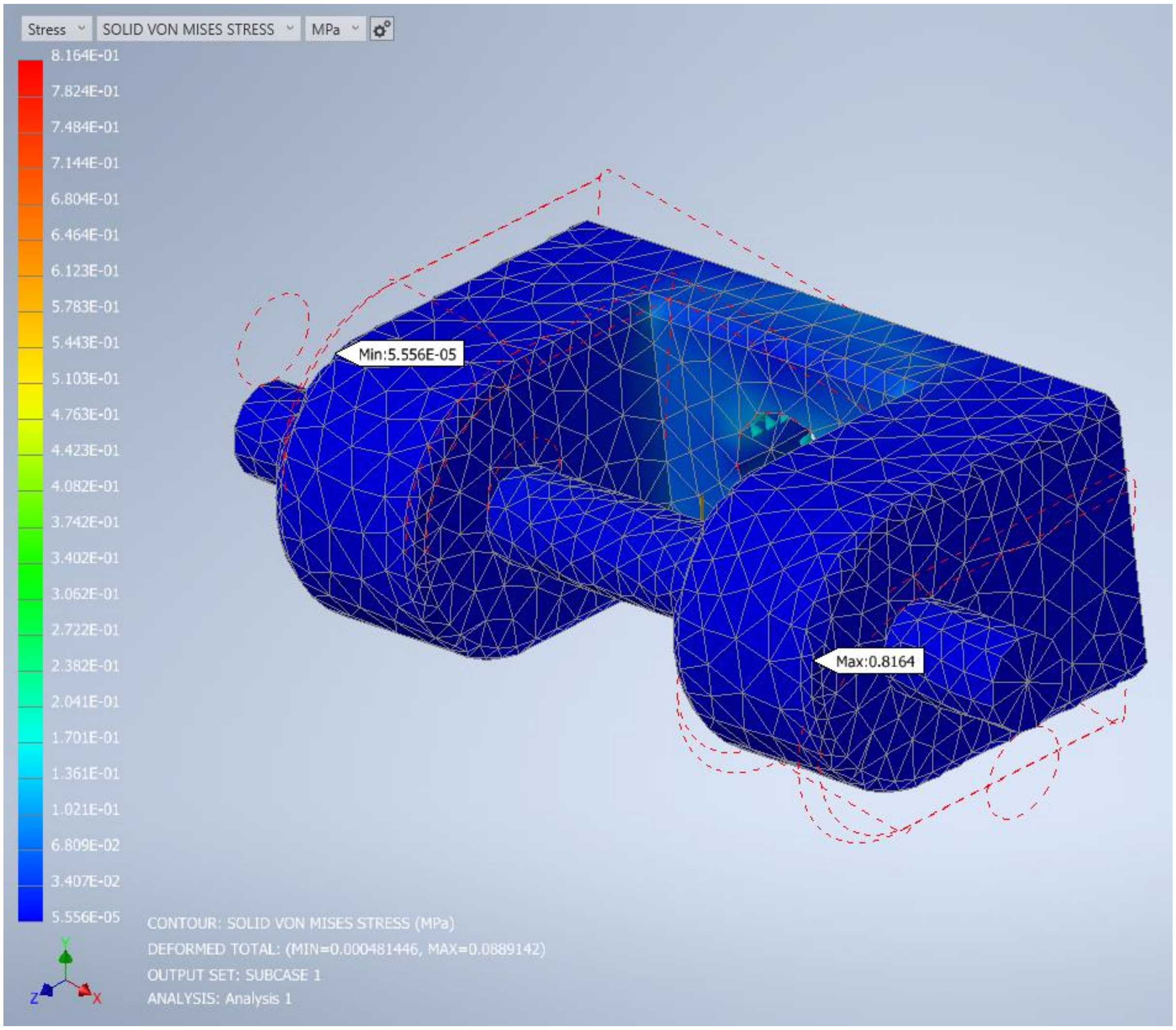




5.4.2 Nastran Finite Elemental Analysis Results

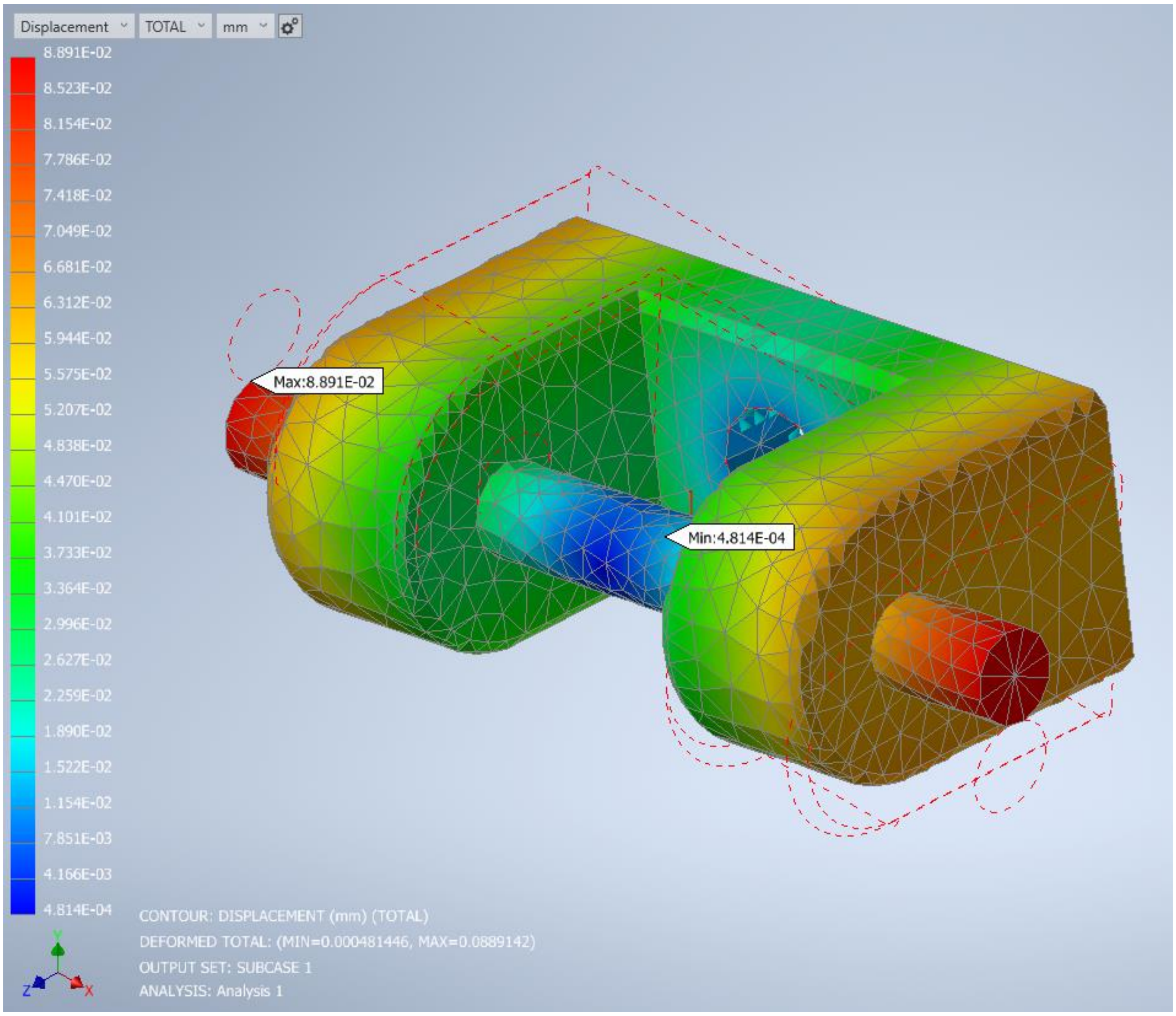
Static linear analysis for subassembly involving hinge plus hinge pin for Orbital Cygnus: 18.1g

Solid Von Mises Stresses:

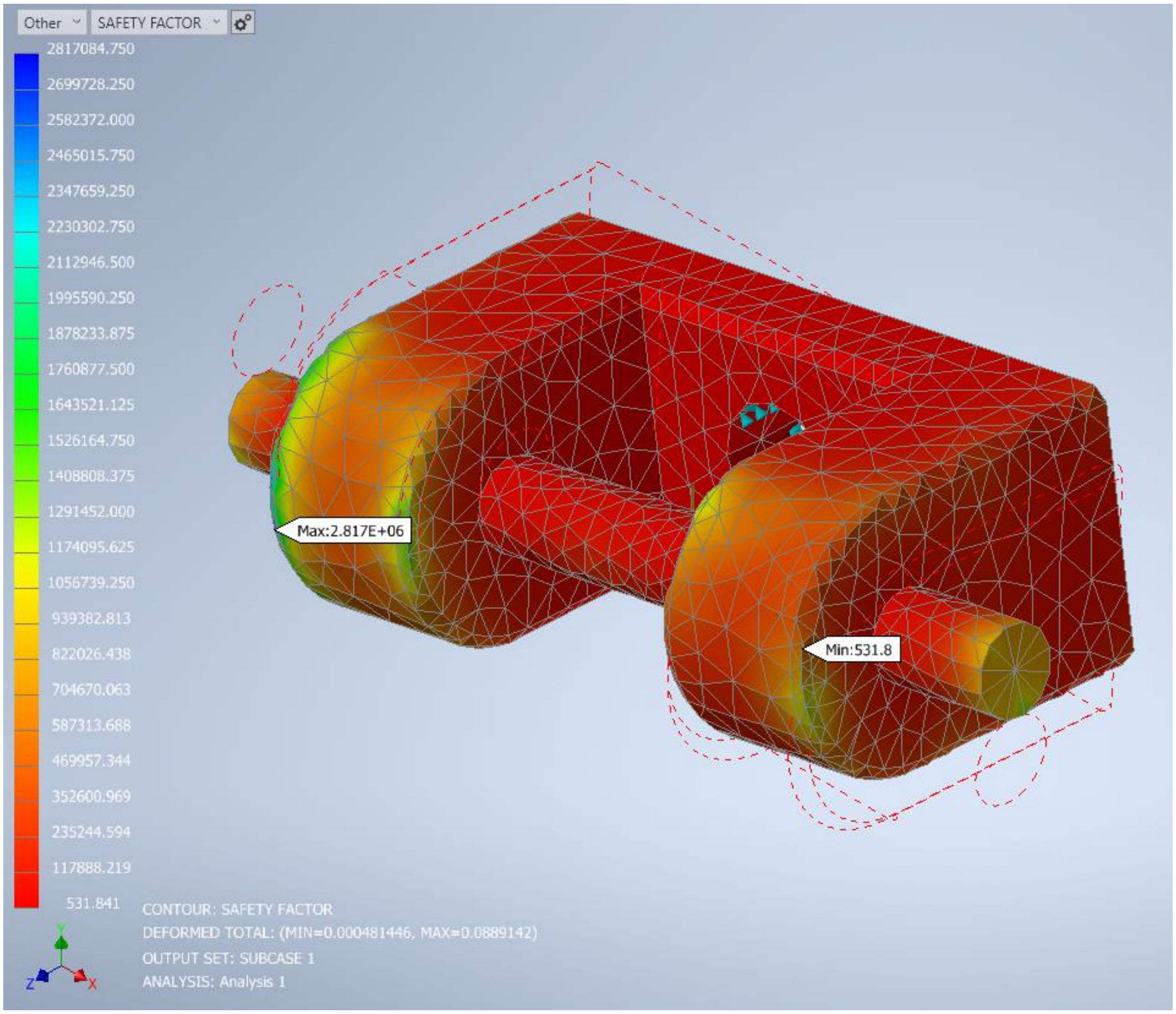


Stress
SOLID VON MISES STRESS
MPa
8.164E-01
7.824E-01
7.484E-01
7.144E-01
6.804E-01
6.464E-01
6.123E-01
5.783E-01
5.443E-01
5.103E-01
4.763E-01
4.423E-01
4.082E-01
3.742E-01
3.402E-01
3.062E-01
2.722E-01
2.382E-01
2.041E-01
1.701E-01
1.361E-01
1.021E-01
6.809E-02
3.407E-02
5.556E-05
Min:5.556E-05
Max:0.8164
CONTOUR: SOLID VON MISES STRESS (MPa)
DEFORMED TOTAL: (MIN=0.000481446, MAX=0.0889142)
OUTPUT SET: SUBCASE 1
ANALYSIS: Analysis 1
Y
Z
X

Displacement:



Safety Factor:



5.5 Reasons for Design

5.5.1 Justification

Out of the three designs, this design is more in line with PAST's plans for their solar panels. The plan for them is to have single solar panels on the XY faces, and a single fixed solar panel on the Z+ face. These tracking hinges work to make this plan a reality. An additional benefit is redundancy. Having separate hinges and motors for each solar panel means that failure of one or more motors will not impede other solar panel tracking. Additionally, having all faces covered in solar panels guarantees some power generation if all motors were to fail. There will also be high power generation when the sun is high (pointing to Z+ face), as all panels (including Z+ panel) will be perpendicular to the sun.

5.5.2 Challenges

One challenge is that the tracking range is limited by having the hinge mechanism on the top face edges. If the sun is high (above Z+ face), panels can hinge up and clear the side of the cube structure and rails. However, if the sun is low (below Z+ face), the corners of the panel can collide with the cube structure and rails.

Additionally, the design takes up significant space in the CubeSats interior, and this is largely due to the high number of motors involved. There are two motors per solar panel (one motor per axis of rotation), which means eight motors total. This also results in a high power cost to the system.

6.0 Conclusion

References

McGill, E. (2018). Development of a Self-Orienting CubeSat Solar Array. https://ecommons.udayton.edu/cgi/viewcontent.cgi?article=1172&context=uhp_theses

Nasa. (2025). https://www.nasa.gov/smallsat-institute/sst-soa/platforms/

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Zhu, Y., Liu, J., & Yang, X. 2020. Design and performance analysis of a solar tracking system with a novel single-axis tracking structure to maximize energy collection. Applied Energy (volume). https://www.sciencedirect.com/science/article/pii/S0306261920301598?casa_token=iyN-3fDCQZIAAAAA:vuCk-mLNqtdsZEYuDpbKcrYAuX471IaJU8x9-xKVNhz3JuNItTHAA_HuXqyBLs-6qp7IxCwM#s0035